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ABSTRACT

In the past few years, teacher training materials on behavior modification have emphasized precise behavioral measurement, and much classroom research has focused on the measurement of academic performance. The most common and simplest recording procedure advocated is frequency count. Difficulties can arise, however, when attempts are made to compare frequencies from day-to-day. Basically, there are three means of interpreting frequency measures--which method is used depends on what the researcher is interested in. In some cases the data can be left in raw form and communicated to others as frequencies. This can take place only when assignment length, available work time, and assignment difficulty are held constant. Two other methods are percentages and rates. These are used when assignment length and/or time vary. Percentages provide information on accuracy, and rates can be used when there is an interest in assessing speed of performance. (Tables demonstrating problems encountered in interpreting frequency measures are included.) (PB)

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INTERPRETING FREQUENCY DATA ON ACADEMIC PERFORMANCE

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During the past five years an increasing number of teacher training materials (e.g., textbooks, programs, journal articles, and books of readings) have been devoted to classroom behavior modification. A major recurring theme throughout these works is an emphasis upon precise behavioral measurement. This emphasis stems from the concern given to such procedures by fellow operant researchers working in the laboratory. Naturally, there are major differences between classrooms and laboratories, and as a result there have been attempts to modify existing laboratory recording procedures, and develop new recording methods more appropriate for classroom settings (e.g., Bijou, Peterson, & Ault, 1973).

For obvious reasons much classroom research has focused upon the measurement of academic performance. Many proponents of classroom management have devoted considerable space to the mechanics of recording academic behavior. The most common and simplest recording procedure advocated is the frequency count. Frequency is defined as the number of times a specific behavior occurs in a unit of time. In a classroom you might, for example, record the number of arithmetic problems completed correctly in a forty-minute period, or the number

of words spelled incorrectly during a daily ten-minute spelling drill. The concept of frequency and the recording of frequency data are quite straightforward, and most teacher training materials present this information clearly. Difficulties can arise, however, in interpreting frequency data once it has been recorded. These difficulties can occur when attempts are made to compare frequencies from day-to-day. There are however, several ways to interpret frequency data so as to make them comparable over time.

Basically, there are three ways to interpret frequency measures. Such data can, under certain conditions, be left in raw form and communicated to others as frequencies. Under other conditions, however, it may be necessary to translate frequencies into either rate or percentage measures, in order to make the data meaningful.

Unfortunately, in an effort to "sell" behavior modification, many training materials have oversimplified behavioral assessment procedures. Many of these training materials have tended to illustrate only the most elementary of interpretation approaches, that of leaving raw frequencies in their original form. Some materials (e.g., Ackerman, 1972; Kunzelman, 1970) have emphasized rate, often to the exclusion of frequency or percentage, while others have provided inadequate information about all three methods of interpreting frequencies (e.g., Blackham & Silberman, 1971; Buckley & Walker, 1970).

Because of these watered-down or biased training devices, an educator proceeding through any one set of materials might develop a

very narrow picture of what to look for and how to assess student academic performance. The purpose of this paper is twofold: First, to identify the conditions under which it is appropriate to report frequency data as frequencies, rates or percentages; and second, to illustrate, via examples from published research and self-generated data, some of the confusion that can occur in analyzing frequency measures.

A recent book by Cooper (1974) states that frequency data on academic performance can be interpreted and reported as simple frequencies only when three conditions are held constant over recording sessions: Assignment length, available work time, and assignment difficulty. Careful examination of published research on classroom management indicates that formal investigations follow these requirements for constancy. In fact, these three requirements are often followed so rigidly that student assignments frequently show repetitions of earlier items (e.g., Ferritor, Buckholdt, Hamblin, & Smith, 1972; Kirby & Shields, 1972). On the other hand, most books and training manuals in classroom management generally do not emphasize these three conditions. Treatment of this topic ranges from virtually ignoring the conditions (e.g., Sulzer & Mayer, 1972) to providing short vignettes which may correctly illustrate the constant conditions, but which do not emphasize either the need for constancy or the problems that might arise if one were to deviate from these requirements. Thus, if an educator was reading a book on classroom behavior modification which only discussed the reporting of simple frequencies, but did not present

complete information on the requirements for such reporting (e.g., Carter, 1972) he might well be faced with the data shown in Table 1.

Insert Table 1 about here

Examination of these data suggest equal performance over the three days. However, if available work time differed on each of these three days, interpretation takes on a new twist. As stated above, raw frequencies can no longer be compared over days because work time is not constant. The appropriate interpretation procedure becomes percentage or rate, although our hypothetical educator reading the frequency-oriented training text would not be aware of this approach.

Actually, of even greater concern than the above problem is the extent to which frequency interpretations are feasible in everyday classrooms. In our experience it is the exception rather than the rule that teachers assign academic tasks which are consistently equal in length, difficulty and available work time. When one considers that behavior modification applications consist at the least, of baseline and reinforcement phases and occasionally, reversal, reinstatement of reinforcement and post-check phases, one begins to appreciate the number of days that such procedures entail. This reduces even further the likelihood that constant conditions will be maintained, and, as a result we question the practicality of the raw frequency interpretation method.

When assignment length and/or time vary from day-to-day, it is necessary to translate simple frequencies into percentages or rates.

Which one you choose depends upon your interests. Percentages provide information on accuracy. The mechanics of calculating percentages present no difficulty. However, two issues regarding percentages need to be examined in terms of their implications for the training of educators. First, as Cooper (1974) and Guilford (1965) argued, percentages should ideally be calculated only when the divisor is 100. However, if a lower limit is to be set it should be no less than 25. The reason for this requirement is that divisors less than 25 result in artificially inflated changes in percentages when the numerator varies by only a small amount. In spite of this potential problem some training materials in classroom behavior modification have ignored this issue, perhaps assuming that educators will "learn" these concepts elsewhere. This might be a mistaken assumption. Examination of certain published research indicates this very type of percentage misuse. Figures 1 and 2 show the results from two such articles (Hall, Axelrod, Tyler, Grief, Jones, & Robertson, 1972, p. 55; Schutte & Hopkins, 1970, p. 120). While per-

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Insert Figures 1 and 2 about here

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centage changes of up to 80% were reported, the actual change in raw frequency was never more than four responses, usually less. Not only are such dramatic percentage changes misleading to the reader, but publication of these results in respected journals helps to insure the continuation of such practices.

A second concern about percentages relates to the concept of accuracy. Most people refer to percentage measures of academic

performance as accuracy. Unfortunately, there are two methods for calculating accuracy and usually little attention is given to how these two performance measures differ. In extreme cases, in fact, (Ayllon & Roberts, 1974) no mention is even made of which accuracy formula has been used. Accuracy can be based on the number of items correct divided by the number of items assigned, or, the number of items correct divided by the number of items attempted. Under certain conditions, when a student always attempts all items, these two measures are identical. However, at other times these formula can produce widely discrepant results. One formula can show an increase in accuracy while the other shows a decrease. With either formula accuracy can be shown to increase, over time, even though the number of items correct remains perfectly stable, or even if items correct decrease. A recent paper by the first author (Klein, 1975) details these changes. In the present paper we will just briefly portray one such example. Figure 3 shows arithmetic performance for a class of third-grade students (Ferritor

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Insert Figure 3 about here

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et al., 1972, p. 15). The data portrayed by the solid lines connecting circles are the median number of correct problems. You can calculate one measure of accuracy, based on items assigned by dividing the median number correct by assigned items. In this experiment, students were always assigned 100 items. Thus, in looking at the first two phases of the study it is seen that number correct remained stable as did accuracy based on items assigned. However, the data portrayed by the dotted lines connecting squares shows quite an increase from Phase One

to Phase Two. These data also happen to represent accuracy--accuracy based on items attempted. In looking at the third and fourth phases of the study one accuracy measure is seen to be increasing while the other decreases and vice-versa. These data not only demonstrate the need to better inform our colleagues of the various interpretation methods available, but they also suggest, perhaps more importantly, that we need to know exactly what we are interested in changing.

Frequency data can be translated into rates when there is an interest in assessing speed of performance. Rate is simply performance divided by time. Rate has not been a popular measure with educators. Several texts on classroom behavior modification do treat the topic thoroughly, (e.g., Ackerman, 1969; Kunzelman, 1970), but most books and journal articles in this area still favor frequency and percentage. With regard to academic performance one can present correct rate, error rate, and the sum of these two--total rate. The latter measure, total rate, really has very little meaning, independent of either correct or error rate. In spite of this, total rate was the only measure reported in one of the first published classroom behavior modification investigations (Lovitt & Curtiss, 1969). In that research children were reinforced for accurate academic performance, but in reporting their results the authors refer only to increases in responses per minute, without indicating whether these increases were errors or correct items.

Similarly, Buckley and Walker (1970) in their book for teachers introduce the concept of rate of academic performance, however, they only illustrate the use of correct rate. To demonstrate some of the

confusion that could develop if you looked only at this one variable, and to summarize some of our points thus far, Table 2 presents an extension of the data presented in Table 1.

Insert Table 2 about here

This particular example shows a student whose correct rate is increasing. However, his error rate is also increasing, while both items correct, and the two measures of accuracy remain unchanged. If the educator was concerned only with correct rate he would see a gradual daily improvement. However, our recommendation based on data such as those in Table 2 is that the educator should not put all of his eggs in one basket. Most importantly, the educator, rather than a book or training program, should decide exactly what performance measures are significant for the students with whom he is working. Such decisions can only be made fairly when sufficient information is provided.

Although we realize that games can be played with data, for illustrative purposes, we believe more strongly that the omission of data interpretation procedures in the training of educators can be quite damaging. We leave you with the data presented in Table 3 as one such possible example.

Insert Table 3 about here

Given a constant assignment length the data in Table 3 shows a decreasing accuracy rate based on items assigned, a stable correct rate, a

stable accuracy rate based on items attempted, and an increasing error rate. What is really happening? It depends on what you are interested in.

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TABLE I

Days	Items Assigned	Items Attempted	Items Correct	Errors
1	30	30	25	5
2	30	30	25	5
3	30	30	25	5

TABLE 2

Days	Items Assigned	Items Attempted	Items Correct	Errors	Time (minutes)	Correct / Attempted	Correct / Assigned	Correct Rate	Error Rate
1	30	30	25	5	25	83%	83%	1/min.	.2/min.
2	30	30	25	5	20	83%	83%	1.25/ min.	.25/ min.
3	30	30	25	5	15	83%	83%	1.67/ min.	.33/ min.

TABLE 3

Days	Items Assigned	Items Attempted	Items Correct	Errors	Time (minutes)	Correct / Attempted	Correct / Assigned	Correct Rate	Error Rate
1	100	80	60	40	50	75%	60%	1.2/ min.	.8/min.
2	100	40	30	70	25	75%	30%	1.2/ min.	2.8/ min.

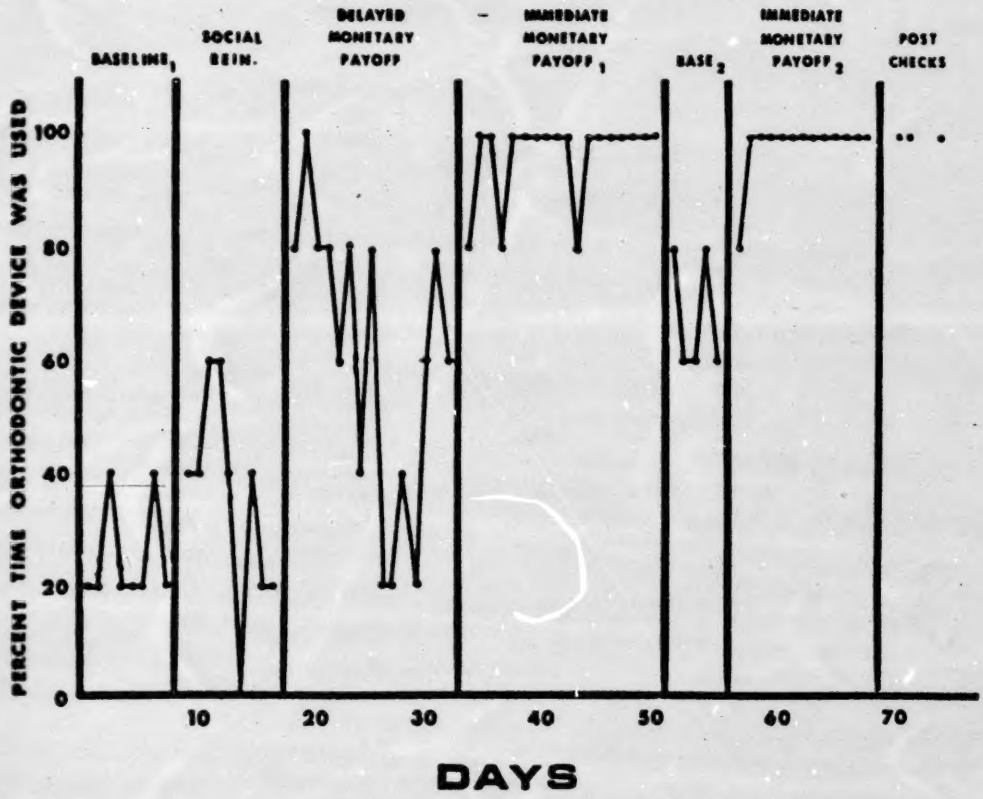

Figure 1. A record of the percentage of time a teen-age boy used an orthodonic device. (From R. Vance Hall et al., 1972, p. 55.)

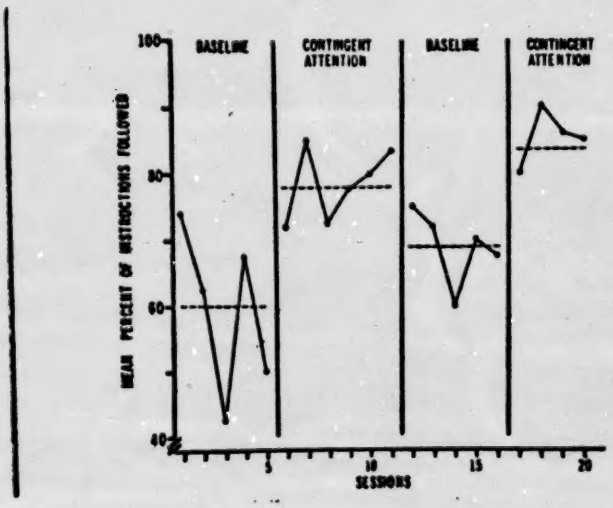

Figure 2. The daily mean percent of instructions followed by all subjects for each session. (From R. C. Schutte and B. L. Hopkins, 1970, p. 120.)

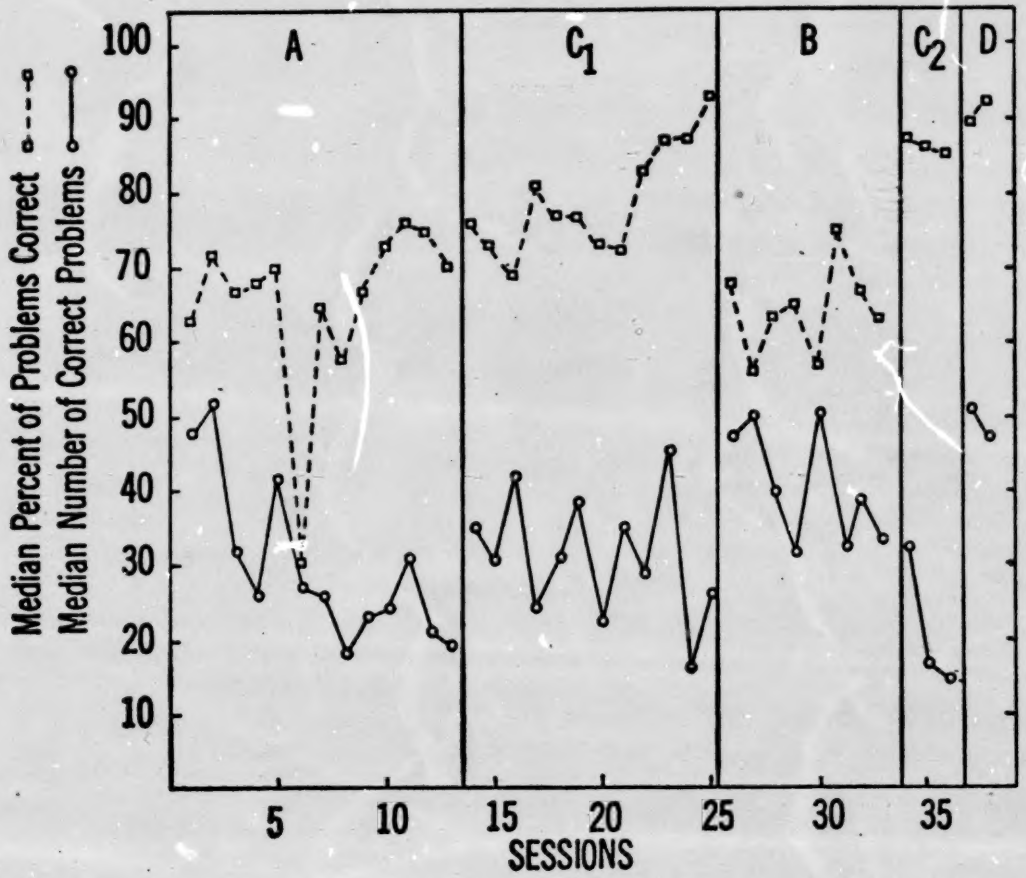

Figure 3. Median number of arithmetic problems worked correctly and median percent worked correctly for a group of nine third graders working 100 computational problems. (From D. E. Ferritor, et al., 1972, p. 15.)